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J/ψ production at high p_T at STAR

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Abstract

We report results on J/ψ-hadron azimuthal angular correlations in 200 GeV p+p collision in the STAR experiment at RHIC. The extracted B-hadron feed-down contribution to inclusive J/ψ yield is found to be 10-25% in $4 < p_T < 12$ GeV/c and has no significant center-of-mass energy dependence from RHIC to LHC. The p_T spectrum of charged hadron associated with high-p_T J/ψ triggers on the away side is found to be consistent with that from di-hadron correlations. J/ψ signal from partially produced Au+Au 39 GeV data will also be presented to demonstrate STAR's J/ψ capability at RHIC low energy run.

Keywords: J/ψ, high p_T, color screening, correlation

1. Introduction

The dissociation of J/ψ due to color-screening of their constituent quarks in a Quark-Gluon Plasma (QGP) is a classic signature for deconfinement in relativistic heavy-ion collisions [1]. Results from the PHENIX experiment at RHIC show that the suppression of J/ψ as a function of centrality (the number of participants) is similar to that observed by NA50 and NA60 at the CERN-SPS, even though the temperature and energy density reached in these collisions is significantly lower than at RHIC [2]. This indicates that additional mechanisms, such as recombination of charm quarks in the later stage of the collision and/or suppression of feed-down contribution from charmonium excited states or B-hadrons, may play an important role; they will need to be studied systematically before conclusion from the observed suppression pattern can be drawn. Recently, the STAR experiment has extended J/ψ suppression measurement to high p_T in Cu+Cu collisions and found that the J/ψ nuclear modification factor R_{AA} is consistent with no J/ψ suppression at $p_T > 5$ GeV/c, in contrast to the prediction from a theoretical model of quarkonium dissociation in a strongly coupled liquid using an AdS/CFT approach [3, 4]. The project is not yet complete and we need to increase the statistics, investigate the meachanism of J/ψ formation, and perform the same measurement with a larger system (Au+Au). On the other hand, measurements from CDF shows that the contribution of B-hadrons relative to the inclusive J/ψ yield in $p + \bar{p}$ collisions at 1.96 TeV significantly increases with increasing p_T. The same measurement at RHIC energy will be also essentially needed to disentangle the physics origin of the high-p_T J/ψ suppression measurements [5].

B was rarely studied at RHIC in the past ten years. The $B \rightarrow J/\psi$ measurements in heavy-ion collisions at STAR are still difficult without a precise vertex detector. But it can be done in p+p collisions through J/ψ-hadron correlations, originally proposed and studied by UA1 [6]. Furthermore, J/ψ-hadron correlations can be also used to study the hadronic activity produced in association with a high-p_T J/ψ to investigate its production mechanism which is still poorly understood more than 30 years after the discovery of J/ψ.

In this paper we present the measurement of the correlation between high-p_T J/ψ's and charged hadrons at mid-rapidity with the STAR experiment in $p + p$ collisions at $\sqrt{s} = 200$ GeV in RHIC year 2009 high luminosity run. We

also report the status of measurement of J/ψ in Au+Au collisions at $\sqrt{s_{\rm NN}}$ = 39 GeV (an energy between CERN-SPS and RHIC top energies) at STAR with newly fully-installed Time-Of-Flight (TOF) detector [7, 8, 9].

2. high-p_T J/ψ production in p+p collisions at 200 GeV

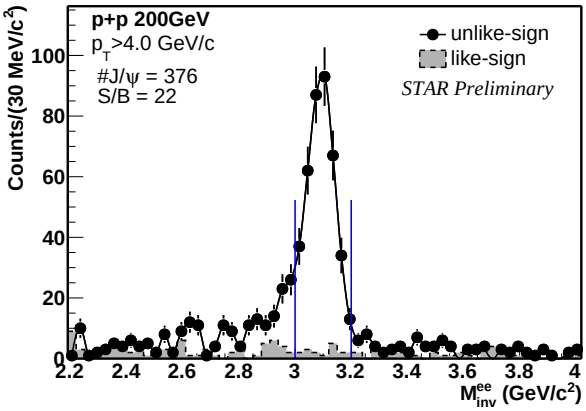

Figure 1: Invariant mass distribution for unlike-sign (solid circles) and like-sign (grey band) electron pairs at mid-rapidity ($|y| < 1$) in p+p collisions at $\sqrt{s_{\rm NN}}$ =200 GeV.

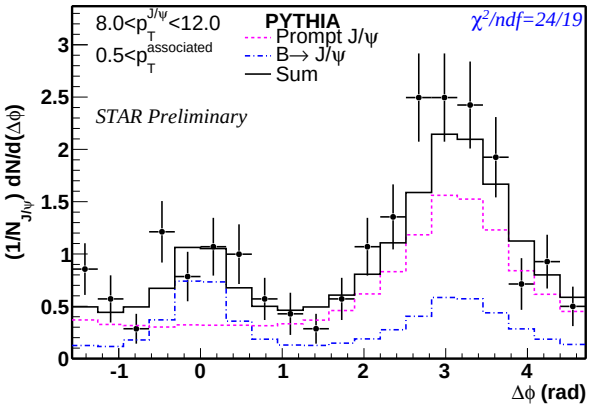

Figure 2: J/ψ-hadron azimuthal angular correlations in the J/ψ p_T range of 8 < p_T < 12 GeV/c at mid-rapidity ($|y| < 1$) in p+p collisions at $\sqrt{s_{\rm NN}}$ =200 GeV.

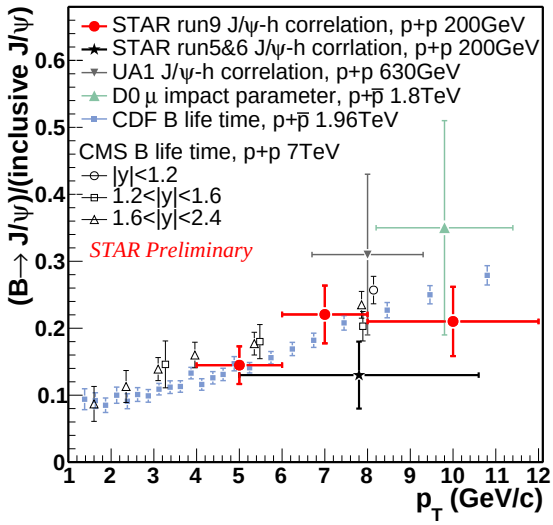

Figure 3: Fraction of $B \rightarrow J/\psi$ over the inclusive J/ψ yield from two sets of run at STAR. The same ratios measured by UA1, D0, CDF and CMS collaborations are also shown for comparison.

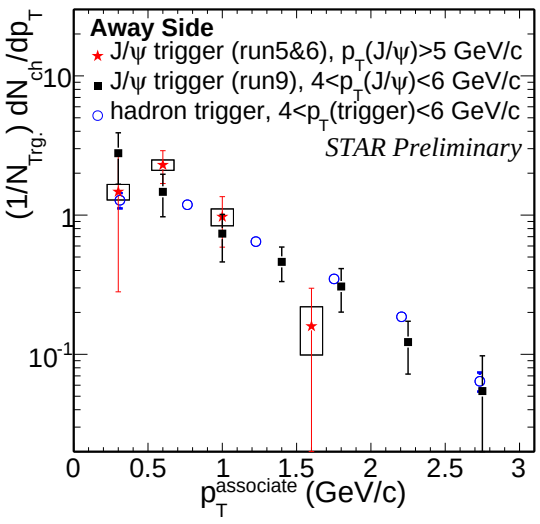

Figure 4: Associated charged hadron p_T distributions on the away side with respect to high-p_T J/ψ triggers and charged hadron triggers at mid-rapidity in p+p collisions at $\sqrt{s_{\rm NN}}$ =200 GeV.

In this analysis, the J/ψ is reconstructed through its decay into electron-position pairs, $J/\psi \rightarrow e^+e^-$ (Branching ratio (B) = 5.9%). The data sample used was triggered at level-0 by the STAR Barrel Electromagnetic Calorimeter (BEMC) by requiring the transverse energy deposited in any tower ($\Delta\eta \times \Delta\phi = 0.05 \times 0.05$) above a given high-energy threshold to enrich high-p_T electrons. This effectively enriches high-p_T J/ψ with limited data acquisition rate. The integrated luminosity is 1.8 pb^{-1}, 3.2 pb^{-1} and 23.1 pb^{-1} with transverse energy threshold 2.6 GeV < E_T < 4.3 GeV, E_T > 4.3 GeV and E_T > 6.0 GeV respectively. The reconstruction method is similar as what we used in year 2005 and year 2006 data. We tightened the dE/dx cut slightly to enhance the signal-to-background (S/B) ratio for the correlation

study [3, 10]. In year 2009, STAR installed 72% TOF trays at mid-rapidity ($|\eta| < 0.9$). This detector combined with the Time Projection Chamber (TPC) can clearly identify electrons from low to high p_T by rejecting hadrons at low and intermediate p_T range. To further improve the S/B ratio of J/ψ, we also require the electron which does not trigger the BEMC to have $1/\beta$ measured by TOF within 0.97-1.03 when its p_T is less than 1 GeV/c [11]. Figure 1 shows the invariant mass distribution for unlike-sign (solid circles) and like-sign (shaded band) electron pairs. We reconstructed 376 J/ψ with $3.0 < M < 3.2$ GeV/c^2 at $p_T > 4$ GeV/c. The S/B ratio in this range is 22. Such high S/B ratio is very suitable for the J/ψ-hadron correlation study. We do the correlation in 3 J/ψ p_T slices: $4-6$ GeV/c, $6-8$ GeV/c and $8-12$ GeV/c. Figure 2 shows the azimuthal angle correlations between high-p_T J/ψ of $8-12$ GeV/c and charged hadrons. The correlated yield on the near-side is not as significant at that in the di-hadron correlation measurements [12]. The lines show the results of a PYTHIA calculation. The dot-dashed line exhibits a strong near-side correlation compared to the away-side dominantly from the decay $B \to J/\psi + X$. The solid line shows a χ^2 fit with the two simulated components to extract the relative contribution of B-hadron feed-down to the inclusive J/ψ yield. This ratio is 10%-25% in the measured p_T range, shown in Fig. 3 in red solid circles, increases with increasing p_T. The results are consistent with STAR's previous measurement (solid star symbol), but with better precision [3]. The same ratios measured by UA1 in $p+p$ collisions at 630 GeV, by D0 (CDF) in $p + \bar{p}$ collisions at 1.8 (1.96) TeV and by CMS in $p + p$ collisions at 7 TeV in various rapidity ranges are also shown for comparison [5, 6, 13, 14]. They are consistent with each other even though the center-of-mass energies differ by an order of magnitude. The ATLAS and LHCb collaborations also observed a similar behavior [15, 16]. The physics origin of this consistency is still unclear. With such an amount of B-hadron feed-down fraction, combined with this J/ψ-hadron correlation study, further study of J/ψ cross-section will allow us to constrain the B cross-section substantially in the future.

Figure 4 shows the associated charged hadron p_T distribution on the away side with respect to high-p_T J/ψ triggers and high-p_T charged hadron triggers. The p_T spectra of charged hadron associated with high-p_T J/ψ are consistent from different runs, but year 2009 results have a better precision. To compare the results with those from di-hadron correlation, we require J/ψ triggers in year 2009 run within the same p_T window as charged hadron triggers: $4-6$ GeV/c. The p_T spectra of the associated charged hadrons with respect to both kinds of triggers are consistent with each other, which indicates that the hadrons on the away side of J/ψ triggers are dominantly from light quark or gluon fragmentation, instead of heavy quark fragmentation.

3. J/ψ production in Au+Au collisions at 39 GeV

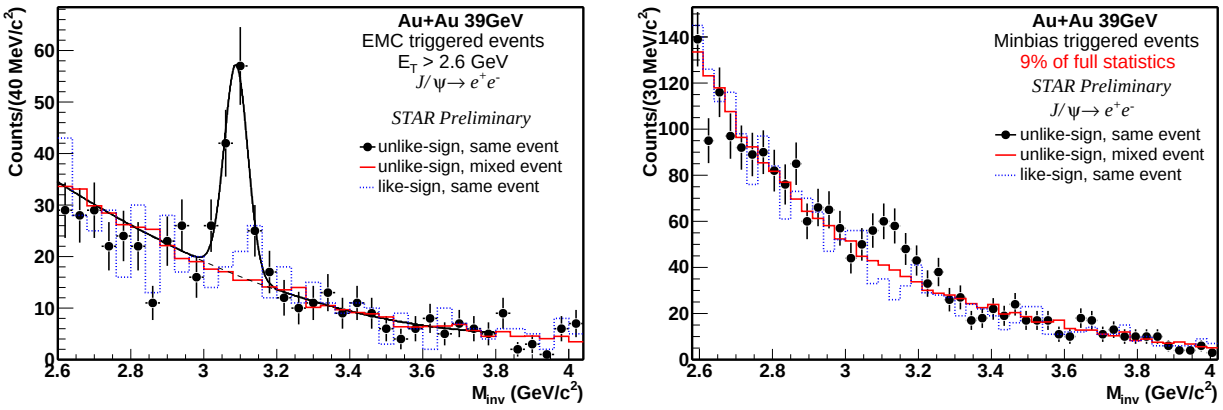

Figure 5: Invariant mass distribution of electron pairs in BEMC triggered (left) and minimum-bias (right) triggered Au+Au events at $\sqrt{s_{\rm NN}}$ =39 GeV. The solid and dashed histograms represent background reproduced using like-sign and mixed-event technique respectively.

The consistency of J/ψ R_{AA} at midrapidity at RHIC and SPS top energies is still a puzzle. Two kinds of models with very different physics origins (recombination models and sequential dissociation models) can qualitatively explain this feature. The measurements of R_{AA} in heavy-ion collisions at a center-of-mass energy between RHIC and SPS top energies are crucial to test these models. The RHIC Beam Energy Scan (BES) program enables such measurements (the reference data for R_{AA} determination already exist). STAR has recorded hundreds of million Au+Au

events at $\sqrt{s_{\rm NN}}$ = 39, 62 and 200 GeV respectively during year 2010 run. Figure 5 shows J/ψ signal from partially produced 39 GeV Au+Au data to demonstrate STAR's J/ψ capability at RHIC low energy run.

The left panel of Fig. 5 shows the invariant mass distributions for electron pairs in BEMC triggered events. The electron identification and J/ψ reconstruction is similar as what we used in year 2009 p+p data. The S/B ratio is lower than that in p+p collisions as expected, but still very high. To improve the statistics, we also reproduce the combinatorial background using mixed-event technique. It is consistent with that from like-sign technique in the mass range shown in the figure. We observed 82 ± 13 (6 σ) J/ψ from this dataset, mainly at $p_T > 2$ GeV/c. To study J/ψ production at low p_T, we also analyzed minimum-bias (MB) triggered data. In this analysis, we excluded BEMC from electron identification due to its inefficiency at low p_T. The signal is shown in the right panel of Fig. 5. 91 ± 22 (4 σ) J/ψ were observed from this 9% of full dataset, 52 in p_T range 0-2 GeV/c and 39 in p_T range 2-4 GeV/c. We expect $\sim$ 1000 (13 σ) J/ψ signal from the full MB dataset. Our projection shows STAR even has the capability to measure J/ψ at 27 and 18 GeV with 1-2 weeks beam time in RHIC year 2011 run.

4. Summary

In summary, we reported results on J/ψ-hadron correlation in p+p collisions at $\sqrt{s}$ =200 GeV and J/ψ signal in Au+Au collisions at $\sqrt{s_{\rm NN}}$ =39 GeV from the STAR experiment at RHIC. The fraction of B-hadron feed-down contribution to inclusive J/ψ yield in p+p collisions was extracted from the J/ψ-hadron correlation and found to be 10-25% in $4 < p_T < 12$ GeV/c, with no significant dependence on center-of-mass energy. The p_T spectra of charged hadron associated with both high-p_T J/ψ triggers and high-p_T charged hadron triggers on the away side were found to be consistent, which indicates the hadron production on the away side is not dominantly from heavy quark fragmentation. STAR observed 6 σ J/ψ signal (mainly at $p_T > 2$ GeV/c) in BEMC triggered 39 GeV Au+Au events, and 4 σ signal in 9% produced MB 39 GeV Au+Au events.

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